Ocean Carbon from Space Workshop

2nd Workshop in the CLEO (Colour and Light in the ocean from Earth Observation) Series

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Report on Crosscutting theme: Blue Carbon

Co-Chairs:
Maria Tzortziou - City College of New York
Emily Pidgeon – Conservation International

Summary:

Blue carbon ecosystems – tidal marshes, mangroves, and seagrass beds – are some of the most carbon-dense habitats on Earth. These highly productive ecosystems provide numerous benefits and services essential for both climate change mitigation and climate change adaptation. Services and benefits include coastal storm and sea level protection, water quality regulation, wildlife habitat, biodiversity, shoreline stabilization, and food security. These ecosystems are also particularly important for their capacity to sequester vast amounts of carbon and store it in their biomass and their soils. However, carbon sequestration capacity, carbon storage, as well as carbon export in blue carbon ecosystems depend on many critical processes including inundation dynamics, sea level rise, air- and water pollution, changes in salinity regimes, and rising temperatures. This session focused on the role that blue carbon habitat play in regional and global carbon budgets and fluxes, and how Earth observations can uniquely contribute to understanding carbon cycling in these highly valuable but also exceedingly vulnerable ecosystems.

The spatial extent of blue carbon ecosystems, and its change, is one of the biggest unknowns and largest sources of uncertainty in quantifying the role of these systems in global carbon budgets and fluxes. The first talk, presented by Silvia Huber (Danish Hydraulic Institute) discussed applications of Sentinel-2 imagery to mapping and monitoring submerged aquatic vegetation (SAV) habitat, such as kelp forests, eelgrass meadows and rockweed beds. Up-to-date knowledge about SAV spatial distribution, abundance, spatial extent, and growth dynamics is critical to protect these threatened ecosystems and assess the effectiveness of SAV management strategies and conservation efforts. Yet, monitoring and mapping these habitat remains a challenge, with most applied survey methods being too time and labor intensive for large scale application. Huber et al. presented an innovative approach for nationwide mapping of coastal SAV habitats at 10 m spatial resolution with Copernicus Sentinel-2 imagery. By applying a combination of Copernicus Sentinel-2 satellite data, novel machine learning techniques and advanced data processing, Huber et al. created the first nationwide overview of the distribution of shallow water vegetation in Denmark and Sweden in 2018 and 2020, respectively. In addition, they wrapped the entire methodological workflow into an easy-to-use web application for non-technical specialists. The presentation provided a demonstration of this tool, followed by a discussion of the methods implemented, as well as the benefits and limitations of this new SAV mapping approach.

The second talk, presented by Victoria Hill (Old Dominion University) discussed application of high frequency and high spatial resolution images available from the PlanetScope constellation to estimates of seagrass density and blue carbon. Remote detection of seagrass in turbid coastal waters has been challenging with most high-spatial resolution satellite sensors, due to the need for satellite passes coincident with low tide and low turbidity conditions to detect seagrass. Commercial high-resolution satellites from the PlanetScope constellation provide daily coverage of the coastal waters of the US – and often multiple passes per day from different sensors – allowing to overcome previous issues with turbidity and tidal state. Hill et al. used the high frequency of passes available from PlanetScope to retrieve distribution and density of seagrass in the coastal bays of Virginia for 2019, 2020 and 2021. The changing distribution and density of seagrass habitat from the spring through the summer was detected, highlighting the reduction in seagrass density after the warm summer months. Hill et al. concluded that this is a promising approach for monitoring seagrass (or submerged aquatic vegetation) density throughout the Chesapeake Bay, an area that has been difficult to monitor from satellites in the past. They also highlighted the need to address atmospheric correction issues.

Ghuanmin Hu (University of South Florida) continued the discussion on remote sensing of blue carbon with a presentation on the role of pelagic macroalgae blooms (including *Sargassum* blooms) in carbon fixation and sequestration. Blooms of pelagic macroalgae have been reported around the world, and long-term remote sensing observations suggest an increasing severity and frequency in recent years. Yet, the role of such macroalgae blooms in ocean carbon fixation and sequestration is not well quantified. Hu et al. used published values on macroalgae coverage, biomass density, carbon/biomass ratio, primary productivity, and carbon sequestration efficiency, to provide first-order carbon estimates of pelagic macroalgae. They found that, compared to phytoplankton, pelagic macroalgae may contribute significantly to carbon stock, carbon fixation, and carbon sequestration in the macroalgae "niche" area, but such a role may diminish when the area is enlarged at basin scales. This presentation also provided an opportunity to discuss the value of future satellite hyperspectral imagery (e.g., from upcoming satellite ocean color sensors such as PACE and GLIMR) for space-based retrievals and spectral discrimination of floating algae based on their unique spectral features due to various pigment absorptions and backscattering properties.

The last talk, by Emily Pidgeon (Conservation International) focused on the Blue Carbon Initiative, which has been instrumental in translating science into policy, management and finance tools for conservation and restoration of blue carbon ecosystems. Through the International Blue Carbon Scientific Working Group, the initiative has simultaneously identified key scientific issues needed for these tools and fostered research in these topics, such as the need for direct carbon change and flux measurements. Large scale mapping of ecosystem extent, change, and attributes such as carbon is now essentially needed for blue carbon prioritization and implementation at global to local scales. The first verified carbon credits from mangrove conservation and restoration were recently released for a conservation project in Northern Colombia. Mangrove coverage, change, and analysis of the anthropogenic drivers of loss for this system by NASA (Goldberg et. al., 2020) were essential to the design of this project. Broad application of these types of analyses are now needed in mangrove systems globally, and development of similar tools is needed for seagrass, salt marsh, and kelp ecosystems if blue carbon is to be used a mechanism for conservation and restoration of these ecosystems.

Poster presentations relevant to this session also discussed:

*Blue carbon of sea grasses: A cost effective climate solution (*by Harsha Dias Dahanayake). This study focused on estimating blue carbon in the sea grass meadows in the southern coastal belt of Sri Lanka during the last decade. The authors estimated the extent of sea grasses in the coast including the lagoons using GIS and satellite data from Landsat-8. They also discussed how Sri Lanka can adopt Nationally Determined Contribution (NDC) mitigation actions as per the Paris Agreement, to ensure the ecological health of sea grass ecosystems.

Dynamics of litterfall and litter decomposition in restored mangrove forests of abandoned aquaculture ponds (by Novia Arinda Pradisty). The study found that annual litterfall production from intact and restored mangroves in Perancak Estuary were 10.18 and 13.96 Mg ha^{-1} $year^{-1}$, which translated to approx. 4581 and 6282 Kg C ha^{-1} $year^{-1}$ of annual litterfall carbon stock, respectively. The study concluded that, although restored mangroves had significantly higher plant litterfall production than intact mangroves, no significant difference detected for leaf litter decomposition between these forest types.

Detection and characterization of coastal tidal wetland change on the U.S. Atlantic Coast (by Xiucheng Yang). The authors discussed application of Landsat time series data to track the status of coastal tidal wetlands on the U.S. Atlantic Coast at 30-m spatial resolution from 1986 to 2020. Application of their approach to the northeastern United States showed overall accuracies of approximately 95.8% for cover classification and 99.8% for change characterization.

After the presentations, co-Chairs and session participants discussed the main scientific challenges, gaps, and opportunities for monitoring blue carbon from space. Below, we provide a summary of the main points discussed.

Challenges:

- Many of the approaches are regional, not easily applied (or tested yet) at a global scale.
- Strong temporal variability/dynamics in tidal BC ecosystems (at hourly and tidal scales)
- Uncertainty estimation in carbon fluxes in BC ecosystems
- Impact of atmosphere and water depth on satellite imagery
- Direct or indirect earth observation techniques to monitor the dynamics of sediment carbon in BC ecosystems
- Cost-effective monitoring using EO techniques to track the progress of rehabilitation-restoration in blue carbon ecosystems
- Existing products/approaches are not easily accessible by "users" who have limited remote sensing expertise.

Gaps:

- Lack of measurements on rates (e.g., *Sargassum* carbon fixation and sequestration efficiency)
- Lack of long-term satellite datasets for change detection in BC ecosystems
- Lack of basic ecosystem mapping and change detection for seagrasses and kelp forests

- Lack of models that can give us full carbon budgets (including soil) for these ecosystems globally
- Lack of models that link carbon storage/cycling in terrestrial and aquatic ecosystems
- Lack of products that are suited to project development and carbon accounting

Opportunities:

- High spatial resolution (3-5 meters) imagery from constellation of satellite sensors (e.g., ESA's PlanetScope) provides an unprecedented dataset to study vegetation characteristics in BC ecosystems.
- New hyperspectral observations (e.g., PACE, GLIMR, SBG) at high to medium resolution and global scale, to distinguish differences between mangrove, seagrass, salt marsh species, and estimate satellite products relevant to carbon quality.
- Fusion of hyper-spectral optical and SAR data provides a promising approach for characterization of tidal wetland interfaces, including wetland vegetation characteristics, inundation regimes, and their impact on carbon fluxes.
- Multiple images per day from new geostationary satellite instruments (GLIMR), will allow to capture tidal dynamics in blue carbon ecosystems, and monitor blue carbon ecosystems (e.g., seagrass meadows) under optimum conditions.
- New efforts for development of BC Habitat Mapping Portals that are "user" friendly.

Main outcome of your session, including the recommendations for future priority activities

New sensors and techniques are leading to significant advancements in the spatial and temporal characterization and monitoring in blue carbon ecosystems. These developments are needed to support blue-carbon based conservation and restoration of these critical ecosystems and have been instrumental in the recent development of blue carbon policy and financing by supporting prioritization, assessment, and monitoring. However, products are now needed on global scales, higher spatial and temporal resolutions, and in a broader range of ecosystems to support blue carbon integration into national carbon accounts and to expand the application of carbon financing. Most importantly, the science community must work directly with policy-makers, conservationists and others to ensure advances are tailored to application and that the tools developed are available broadly and equitably.